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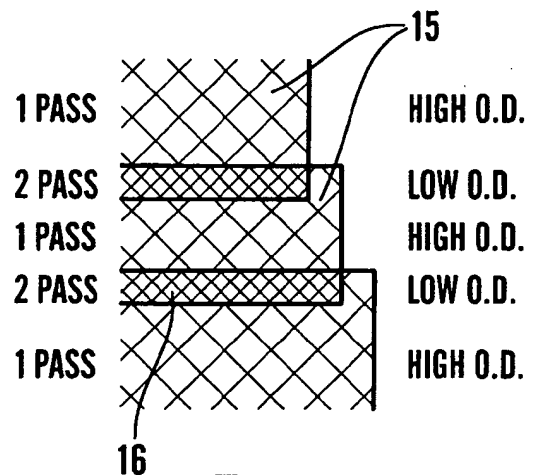
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**(54) Printing apparatus and method**

(57) An inkjet printer prints swaths (14) which overlap by, typically, one eighth of their width at each edge, each edge region (16) having a reduced print density so that the combined density of the overlapping regions matches that of nonoverlapping central regions (16). In a first embodiment, each edge region (16) is printed with 50% printing density. In a second embodiment, the printing mask is modified so that each edge region comprises two sub-regions with differing print densities, e.g. a first outer sub-region (25) with a printing density of 15% and a second sub-region (26) with a printing density of 85 %.



**Fig.5**

## Description

[0001] The present invention relates to inkjet printers, including but not limited to large format printers, and to methods of operation thereof.

[0002] A problem with existing inkjet printheads, comprising a plurality of nozzles arranged substantially in a straight line, is that the nozzles at and adjacent the ends of the printhead or pen tend to eject inkdrops at an angle to a print medium rather than perpendicularly thereto as desired.

[0003] The Hewlett-Packard DesignJet 750 family of printers solved this problem by only using the central nozzles of the pen, thus avoiding the use of those with directionality problems. Since the extreme nozzles were not used at all, this produced clogging of these nozzles and deterioration of the reliability of the pen. In particular, since contaminants generally flow to the extreme nozzles actually being used, some of the central nozzles did not fire correctly. As the number of extreme nozzles with directionality problems increased, the portion of the pen actually being used had to become smaller and smaller to achieve satisfactory quality, which had an adverse effect on throughput.

[0004] Another previously-proposed solution was to print in two-pass mode throughout, but this produced essentially a doubling of printing time, which was not generally acceptable.

[0005] The present invention seeks to overcome or reduce one or more of the above-mentioned problems.

[0006] According to a first aspect of the present invention there is provided an inkjet printing apparatus having a printhead comprising a plurality of nozzles arranged substantially along a printhead axis characterised in that the printing apparatus is arranged to print swaths which overlap their neighbouring swaths by a fraction of the swath width, the regions of each swath which overlap the neighbouring swaths having a reduced print density relative to their central regions.

[0007] According to a second aspect of the present invention, there is provided a method of operating an inkjet printing apparatus having a printhead comprising a plurality of nozzles arranged substantially along a printhead axis characterised in that swaths are printed which overlap their neighbouring swaths by a fraction of the swath width, the regions of each swath which overlap the neighbouring swaths having a reduced print density relative to their central regions.

[0008] Preferred embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, of which:

Fig. 1 is a graph showing a typical profile of angle of inkdrop ejection against nozzle position;

Fig. 2 is a schematic diagram of an inkjet printhead to assist in the explanation of Fig. 1;

Figs. 3a and 3b illustrate the effects of positive and negative swath height error in prior art printing devices;

Fig. 4 shows a schematic diagram of an arrangement in accordance with a first embodiment of the present invention;

Fig. 5 illustrates a problem which can still occur with an arrangement in accordance with Fig. 4;

Fig. 6 illustrates a separate problem which can still occur with an arrangement in accordance with Fig. 4;

Fig. 7 illustrates a schematic diagram similar to Fig. 4 but of an arrangement in accordance with a second embodiment of the present invention; and

Fig. 8 is a diagram corresponding to Fig. 6, but illustrating the output of an arrangement in accordance with Fig. 7.

[0009] Referring to the drawings, Fig. 1 shows a typical directionality profile of inkjet printheads with nozzles arranged along the pen axis. As shown, the profile is a curve which is generally planar in a central region but variable at the ends. In fact the curve often displays much more localised variations than those shown.

[0010] Such profiles produce an effect named Swath Height Error, which will now be explained in connection with Fig. 2. Swath Height Error arises when the height of the printhead (i.e. the dimension along its axis) is not equal to the height of the area actually printed. Fig. 2 shows how a discrepancy arises between the printed swath height "p" and the theoretical swath height "t". The 512 nozzles 11 of printhead 10 are shown as having the profile of Fig. 1 so that the extreme nozzles eject ink in a direction away from the central nozzles, resulting in "p" being greater than "t".

[0011] When printing in one pass, the advance of the medium is equal to the theoretical swath height, producing overlapping of printed areas (positive SHE, see Fig. 3a) or white streaks (negative SHE, see Fig. 3b). Figures 3a and 3b show the printed output of a printhead in adjacent positions 10, 10' with Fig. 3b illustrating the result of the extreme nozzles directing ink in a direction towards the central nozzles, resulting in "p" being less than "t".

[0012] It is not practical to adjust the height of the printed swath, i.e. the unit of printing medium advance, to cater for those defects. Furthermore, the above-mentioned previous proposals have the disadvantage of substantially reducing throughput.

[0013] Figure 4 illustrates an arrangement in accordance with a first embodiment of the present invention in which

at neighbouring positions 30, 30' the printhead is arranged to print swaths 14 with the outputs of their adjacent extreme nozzles overlapping by one eighth of the swath height. Moreover the so-called print masks of the printheads are arranged so that their overlapping extreme nozzles print with a 50% printing density, i.e. simulating a two-pass printing mode, whereas their central nozzles print at 100% as if there was a purely one-pass printing mode. It will be seen that the central nozzles extend over a height corresponding to six-eighths of the swath height. It will also be noted that the advance of the print medium is slightly reduced to seven-eighths of that of the described prior art arrangement.

**[0014]** The above-described arrangement has numerous advantages. For example, by interlacing the passes of the printheads, errors produced by misdirection of ink drops are no longer visible. It still has a relatively fast print mode; the corresponding advance of an arrangement in which, say, the end eighths were completely unused, would be six-eighths, and that of a completely two-pass arrangement would be only four-eighths. The end nozzles of the above-described arrangement are still in continuous use so that contaminants do not move towards the central nozzles.

**[0015]** Various modifications can be made to the above-described arrangement. For example, the numbers given may be changed to suit the particular application. Thus the printhead 30 may have any number of nozzles different from 512. Also the fraction of the overlapping nozzles may vary from just above 0 to approaching one half, with the preferred range lying between one sixteenth and one quarter.

**[0016]** Moreover, steps may be taken to hide any errors produced by contaminants in the extreme nozzles. For example, if it is established that the nth nozzle from the bottom of printhead 30 is blocked, then compensation can be arranged in that the nth nozzle upwards from the top of the central region of the printhead prints at 100% print density.

**[0017]** A second embodiment of the present invention is based on the recognition that problems may arise in the operation of the embodiment of Fig. 4. It should be noted that there is commonly a difference in optical density between a zone printed in one-pass mode and a zone printed in two-pass mode, even with the same amount of ink on the paper. This is due to ink interacting differently with the print medium when the second ink application occurs when the other ink has dried. The banding effect produced is illustrated in Fig. 5 which shows central regions 15 forming areas with a high optical density and the overlapping extreme regions 16 forming zones with a low optical density.

**[0018]** Another problem that may occur is caused by the nozzles at the bottom of the printhead (which produce the first printing in an extreme region) being misaligned with the nozzles at the top of the printhead (which produce the second printing in the extreme region). Such misalignment is more likely to occur in such cases than between adjacent groups of nozzles. Because substantially equal amounts of ink are supplied by each extreme nozzle group, the effects of any slight misalignment become noticeable in extreme regions 16, as shown schematically in Figure 6.

**[0019]** Figure 7 illustrates an arrangement in accordance with the second embodiment of the present invention in which, for each pass of the extreme regions 16 of the printing mask, there are used non-uniform distributions of ink density. In particular the nozzles of the extreme one sixteenth region 25 of each printhead are printed with only 15% printing density, with the next one sixteenth region 26 being printed at 85 % printing density.

**[0020]** Such an arrangement succeeds in still hiding errors without causing too much banding. This is because most of the ink is put on the paper on the same pass, this being less noticeable than the optical density difference due to placing ink in two substantially similar passes. The arrangement is particularly advantageous for line drawings, e.g. CAD drawings, but less so for graphics images. Fig. 8 illustrates that the effects of extreme nozzle misalignment are much less noticeable when only 15% of the dots come from the other pass.

**[0021]** A normal mono mode use of the above arrangements involves only an extra 5 seconds in producing a D size plot (i.e. substantially 47 seconds compared to 42 seconds).

**[0022]** The same modifications may be made to the second embodiment as to the first embodiment. Moreover, the values of the various numbers may be changed. The two density value pairs chosen may vary between 1% and 99% to 49% and 51%, with preferred pairs varying between 5% and 95% to 45% and 55%. Most preferred pairs are the 15% and 85% (as described) and 10% and 90%, and other pairs lying therebetween.

**[0023]** Also the two regions 25, 26 do not need to be of the same extent; they could each occupy 10 to 90% of the combined extreme region.

**[0024]** The edge strip of lower printing density could be located nearer the central nozzles than the adjacent strip of higher printing density, but such an arrangement would be less advantageous since it would place more reliance on nozzles which were more likely to be faulty.

**[0025]** Instead of two edge strips, three or more edge strips of differing print density may be employed.

**[0026]** The arrangements according to the present invention are preferably applied to black ink. However, they may additionally or alternatively be used for colour printheads.

**[0027]** It will be noted that the present invention provides a printing apparatus and method in which a partial two-pass print mode hides end nozzle defects whilst being almost as fast as a single-pass print mode.

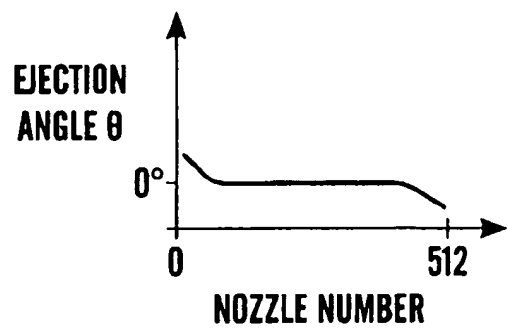
## Claims

1. An inkjet printing apparatus having a printhead (30) comprising a plurality of nozzles arranged along a printhead axis characterised in that the printing apparatus is arranged to print swaths (14) which overlap the neighbouring swaths by a fraction of the swath width, the edge regions (16) of each swath which overlap the neighbouring swaths having a reduced print density relative to their central regions (15).

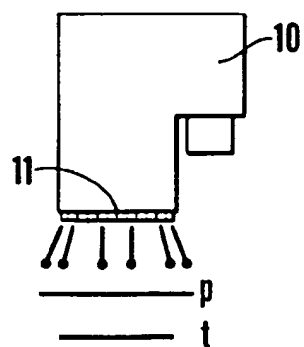
2. A printing apparatus according to claim 1, wherein the overlapping fraction at each edge lies in the range between

one sixteenth and one quarter of the swath width.

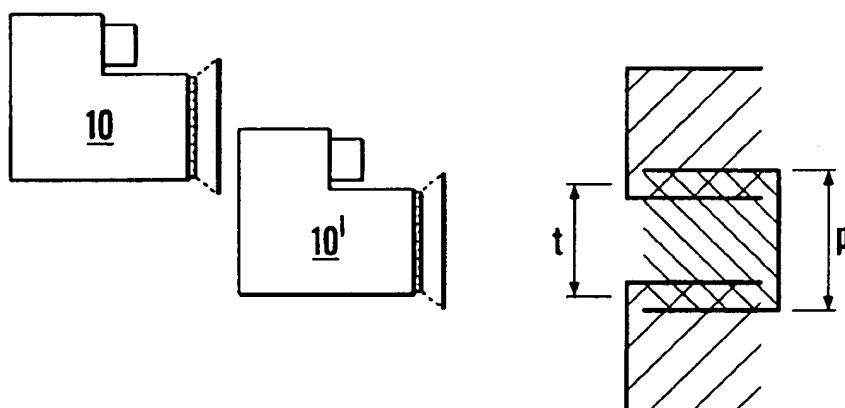
3. A printing apparatus according to claim 2, wherein the overlapping fraction is substantially one eighth of the swath width.
4. A printing apparatus according to any preceding claim, wherein the reduced print density at the edge regions (16) is 50% of the print density at the central regions (15).
5. A printing apparatus according to claim 1, 2 or 3, wherein the edge regions (15) are each divided into two sub-regions (25, 26) of differing print densities.
6. A printing apparatus according to claim 5, wherein the printing density in the edge sub-region (25) is in the range 10 to 15% and the printing density in the adjacent sub-region (26) is in the range 90 to 85%.
7. A printing apparatus according to claims 3 and 6, wherein each of the sub-regions (25, 26) occupy substantially one sixteenth of the swath width.
8. A printing apparatus according to any preceding claim, wherein it prints in black ink.
9. A printing apparatus according to any preceding claim, having at least one non-functional nozzle in an edge region (15) thereof, wherein the printing density of the nozzle in the other edge region (15), which prints along the same path in the adjacent scan, is arranged to print with substantially 100% print density.
10. A method of operating an inkjet printing apparatus having a printhead (30) comprising a plurality of nozzles arranged substantially along a printhead axis characterised in that swaths (14) are printed which overlap the neighbouring swaths by a fraction of the swath width, the edge regions (16) of each swath which overlap the neighbouring swaths having a reduced print density relative to their central regions (15).



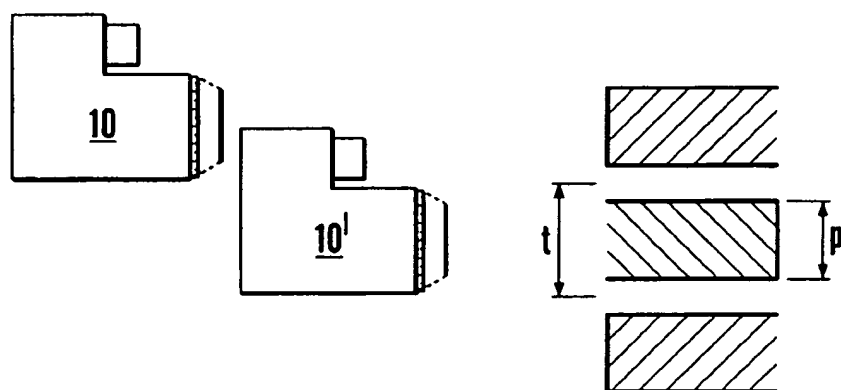
*Fig. 1*



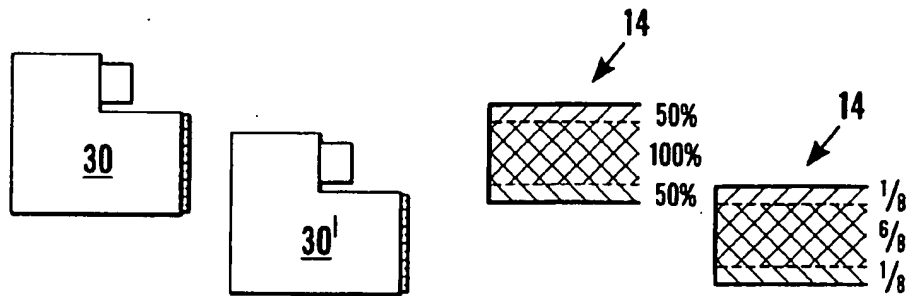
*Fig. 2*



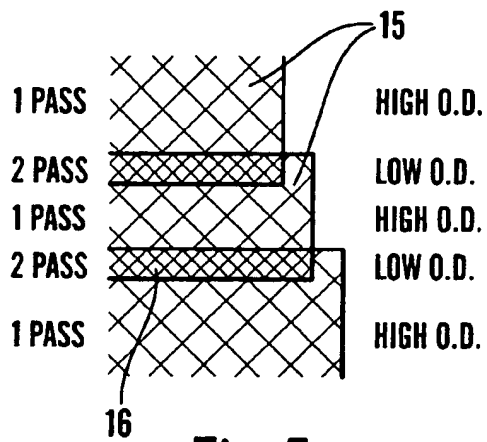
*Fig. 3a*



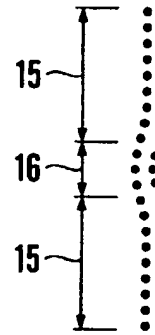
*Fig. 3b*



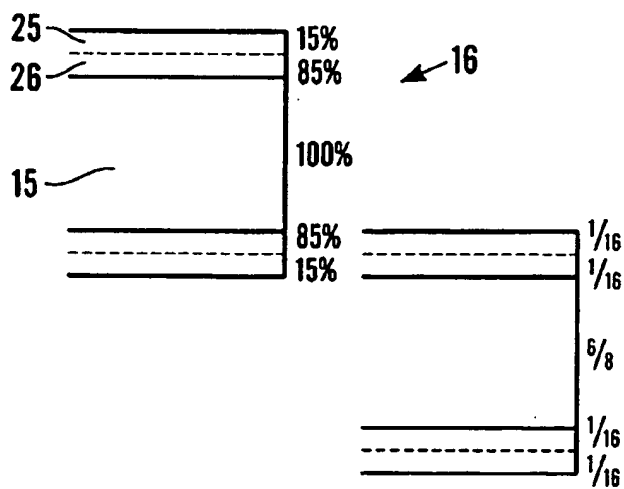
**Fig. 4**



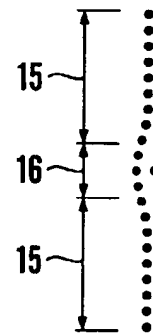
**Fig. 5**



**Fig. 6**



**Fig. 7**



**Fig. 8**



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# EUROPEAN SEARCH REPORT

Application Number  
EP 99 30 1151

DOCUMENTS CONSIDERED TO BE RELEVANT			
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Place of search BERLIN		Date of completion of the search 8 July 1999	Examiner Ducreau, F
<b>CATEGORY OF CITED DOCUMENTS</b> X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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